and latitude 50° S., which was approximately our position at Observatory Bay, we obtain a secular variation of $-2'\cdot3$. We may therefore fairly conclude that $-2'\cdot5$ represents the annual change with considerable accuracy.

Passing from the dip to the total force we find 11·323 to be in British units the mean of three determinations from observations made on shore by H.M.S. 'Erebus' and 'Terror.' If, now, we apply the correction +0·1 for the change from Christmas Harbour to Royal Sound, the result is still somewhat less than the mean of the observations taken near the eastern extremity of Kerguelen during the epoch 1840–45. Adopting 11·423 as the mean value for 1842–45, and 11·143 for 1875, we obtain a secular diminution of 0·0086 in this element of terrestrial magnetism.

The annual increase of the declination will be $+7'\cdot0$, if we take the approximate value of 32·0 W. from the map of Sir E. Sabine as representing the declination for the epoch 1842–45.

## IV. "On the Variations of the Daily Range of the Magnetic Declination as recorded at the Kew Observatory." By Balfour Stewart, LL.D., F.R.S., Professor of Natural Philosophy at the Owens College, Manchester. Received February 28, 1877.

1. The daily range of the magnetic declination at any station may perhaps be regarded as a convenient representative of the magnetic activity of the place. For while a thorough discussion of the diurnal magnetic changes must embrace along with the declination the two components of the force, yet, as regards such daily ranges, the declination gives results which are not only more prominent but also more easily procurable and subject to fewer uncertainties than similar ones for the other two elements.

In estimating the daily range of the magnetic declination, as recorded at the Kew Observatory, I have excluded the disturbed observations, conceiving that by so doing a better indication of the true magnetical activity of the place would be obtained than by including them, inasmuch as they follow a very different set of laws from that of the well-known diurnal declination-range. The disturbed observations have been separated by the method of Sir E. Sabine, those being rejected as disturbed for which the measurements on the photographic curve are 0·150 inch either above or below the mean value for that month and hour, one inch denoting $22'\cdot04$ of angular change. The daily ranges are here given in inches, and they denote the differences between the greatest and least values of each day's hourly tabulations from the curve, disturbances being excluded. I am indebted to the kindness of the Kew Committee for giving me the daily ranges herein discussed, extending from the beginning of 1858 to the end of 1873, thus embracing in all sixteen years' observations.

A. *Annual Variation of Declination-range.*

2. The following Table exhibits mean monthly results of the declination-range corresponding to 48 points in the year. It will afterwards be seen (art. 7) that the declination-range depends amongst other things on the relative position of the sun and moon, and hence to eliminate this inequality I have resorted to monthly means.

TABLE I.—Containing Monthly Means (48 to the year) of the Diurnal Declination-ranges, thus :—January (0) gives the Monthly Mean of which the Middle Date is the very commencement of the Year, January (1) that for one Week after the commencement, and so on.

| Date. | | 1858–61. | 1862–65. | 1866–9. | 1870–3. | Mean. |
|---|---|---|---|---|---|---|
| Jan. | (0) | ·325 | ·320 | ·249 | ·352 | ·312 |
| ,, | (1) | ·334 | ·329 | ·265 | ·367 | ·323 |
| ,, | (2) | ·344 | ·348 | ·279 | ·389 | ·340 |
| ,, | (3) | ·356 | ·363 | ·313 | ·414 | ·362 |
| Feb. | (0) | ·389 | ·369 | ·347 | ·435 | ·385 |
| ,, | (1) | ·414 | ·371 | ·359 | ·458 | ·401 |
| ,, | (2) | ·438 | ·379 | ·378 | ·476 | ·418 |
| ,, | (3) | ·479 | ·389 | ·388 | ·496 | ·438 |
| Mar. | (0) | ·512 | ·418 | ·395 | ·545 | ·467 |
| ,, | (1) | ·554 | ·465 | ·425 | ·589 | ·508 |
| ,, | (2) | ·593 | ·504 | ·463 | ·634 | ·548 |
| ,, | (3) | ·635 | ·538 | ·499 | ·675 | ·587 |
| April | (0) | ·664 | ·554 | ·537 | ·704 | ·615 |
| ,, | (1) | ·689 | ·552 | ·556 | ·731 | ·632 |
| ,, | (2) | ·697 | ·547 | ·555 | ·755 | ·639 |
| ,, | (3) | ·664 | ·535 | ·545 | ·738 | ·620 |
| May | (0) | ·641 | ·526 | ·516 | ·713 | ·599 |
| ,, | (1) | ·605 | ·528 | ·504 | ·688 | ·581 |
| ,, | (2) | ·600 | ·532 | ·508 | ·652 | ·573 |
| ,, | (3) | ·619 | ·549 | ·516 | ·657 | ·586 |
| June | (0) | ·626 | ·568 | ·529 | ·663 | ·596 |
| ,, | (1) | ·637 | ·574 | ·538 | ·669 | ·605 |
| ,, | (2) | ·633 | ·582 | ·541 | ·685 | ·610 |
| ,, | (3) | ·614 | ·581 | ·539 | ·683 | ·604 |
| July | (0) | ·613 | ·566 | ·533 | ·692 | ·601 |
| ,, | (1) | ·606 | ·558 | ·533 | ·692 | ·597 |
| ,, | (2) | ·611 | ·547 | ·526 | ·678 | ·591 |
| ,, | (3) | ·612 | ·537 | ·528 | ·692 | ·593 |
| Aug. | (0) | ·611 | ·546 | ·538 | ·681 | ·594 |
| ,, | (1) | ·623 | ·551 | ·544 | ·684 | ·601 |
| ,, | (2) | ·635 | ·558 | ·550 | ·700 | ·611 |
| ,, | (3) | ·631 | ·562 | ·544 | ·686 | ·606 |
| Sept. | (0) | ·623 | ·547 | ·534 | ·671 | ·594 |

TABLE I. (*continued*).

| Date. | | 1858–61. | 1862–65. | 1866–9. | 1870–3. | Mean. |
|---|---|---|---|---|---|---|
| Sept. | (1) | ·609 | ·540 | ·514 | ·646 | ·577 |
| ,, | (2) | ·581 | ·523 | ·494 | ·621 | ·554 |
| ,, | (3) | ·559 | ·493 | ·481 | ·595 | ·532 |
| Oct. | (0) | ·537 | ·483 | ·458 | ·573 | ·513 |
| ,, | (1) | ·522 | ·464 | ·445 | ·552 | ·496 |
| ,, | (2) | ·504 | ·448 | ·437 | ·522 | ·478 |
| ,, | (3) | ·486 | ·445 | ·418 | ·503 | ·463 |
| Nov. | (0) | ·465 | ·427 | ·408 | ·480 | ·445 |
| ,, | (1) | ·420 | ·402 | ·389 | ·462 | ·418 |
| ,, | (2) | ·389 | ·376 | ·361 | ·430 | ·389 |
| ,, | (3) | ·363 | ·354 | ·333 | ·390 | ·360 |
| Dec. | (0) | ·341 | ·337 | ·309 | ·371 | ·340 |
| ,, | (1) | ·341 | ·321 | ·279 | ·345 | ·322 |
| ,, | (2) | ·323 | ·311 | ·259 | ·339 | ·308 |
| ,, | (3) | ·325 | ·305 | ·254 | ·349 | ·308 |

3. It will be seen from Table I. that while there is a maximum of declination-range in June about the time of the summer solstice, there are also maxima in April and August, and that a behaviour of this kind is indicated in each four years' observations. Comparing this result with that embodying the annual variation of temperature-range at Kew (Proc. Roy. Soc. 1877, vol. xxv. p. 578), it will be seen that the latter variation has only one maximum in July. Perhaps there is a reference to the equinoxes as well as to the solstices in the annual variation of the declination-range. A comparison of the two is exhibited in Figs. IX., X., p. 120 (Fig. IX. giving declination- and Fig. X. temperature-ranges).

B. *Variations of Long Period.*

4. It is well known that the range of the magnetic declination has a long-period variation, apparently connected with the physical state of the sun's surface. In order to investigate the nature and closeness of this connexion the following plan has been adopted:—Let us assume as the most probable hypothesis that the cause which exalts or depresses the mean annual declination-range exalts or depresses also in a similar manner the variations of this from one month to another. This is what would take place if we could imagine the effect to be produced by some influence *emanating* from the sun, which acted more powerfully on some years than on others, while the variations of this effect due to the sun's position in the ecliptic were also altered in the same proportion. On the whole this is borne out by Table I. Constructing, now, a Table for each year, and for 48 points in each year, and reckoning the mean of the 16 years' ranges for each of these points (as exhibited in the last column of Table I.) equal to 1000, we find in Table II. a series of values exhibiting the proportion between the observed range for any point of any one year,

and the mean of the whole 16 years for the same point. For instance, the monthly value corresponding to Feb. (0) 1866 is ·3535, while the normal value for the whole 16 years for this point is (by Table I.) ·385, and hence the proportional value of the range for Feb. (0) 1866 is $1000 \times \frac{\cdot 3535}{\cdot 385} = 918$. By these means it is believed that the results of Table II. are freed from any recognized inequality, depending either on the month of the year or on the relative position of the sun and moon.

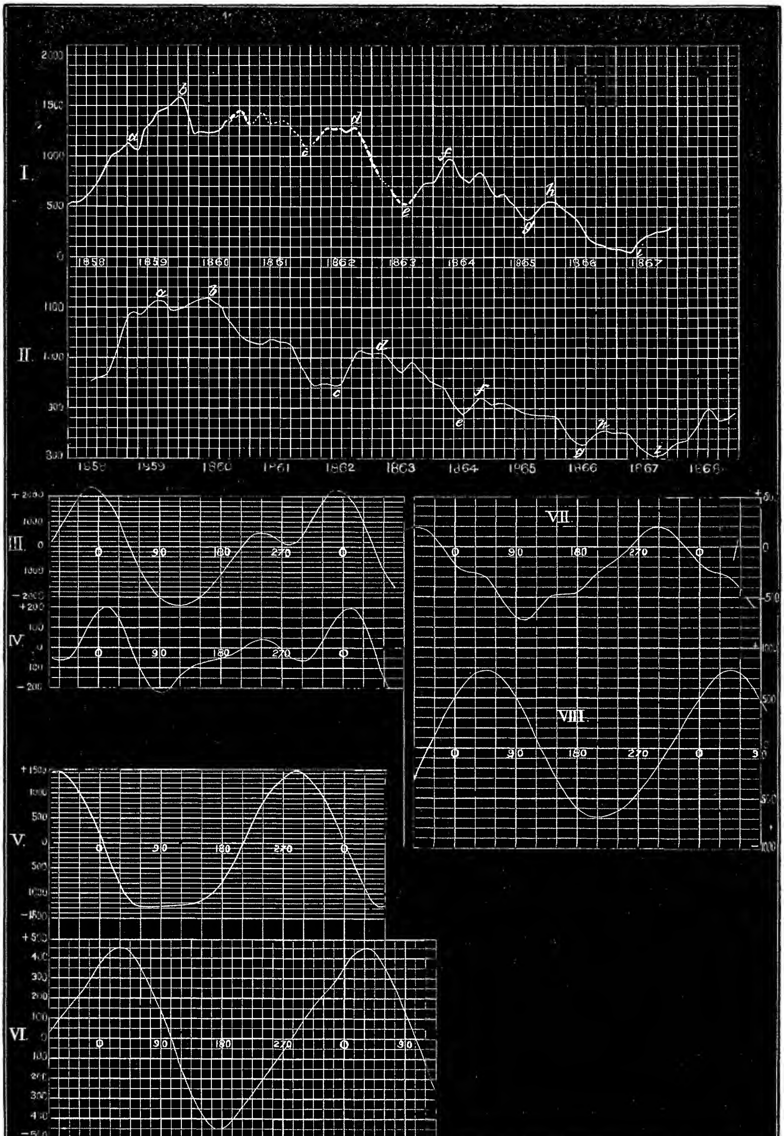


TABLE II.—Exhibiting Monthly Means of Declination-range (48 points to each year), the Mean Value of the Range for the whole Series for each point being reckoned = 1000.

| | | 1858. | 1859. | 1860. | 1861. | 1862. | 1863. | 1864. | 1865. | 1866. | 1867. | 1868. | 1869. | 1870. | 1871. | 1872. | 1873. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| January | (0)......... | — | 1070 | 1140 | 970 | 1015 | 1127 | 979 | 991 | 887 | 921 | 709 | 676 | 913 | 1135 | 1155 | 1217 |
| ,, | (1)......... | — | 1018 | 1132 | 944 | 977 | 1120 | 1007 | 985 | 920 | 923 | 764 | 683 | 972 | 1142 | 1238 | 1203 |
| ,, | (2)......... | 913 | 986 | 1134 | 1017 | 956 | 1146 | 980 | 1011 | 925 | 852 | 793 | 710 | 1006 | 1089 | 1270 | 1212 |
| ,, | (3)......... | 924 | 1007 | 1011 | 1002 | 960 | 1143 | 903 | 1014 | 942 | 870 | 830 | 818 | 1011 | 1094 | 1280 | 1193 |
| February | (0)......... | 966 | 1006 | 1044 | 1028 | 942 | 1048 | 921 | 923 | 918 | 871 | 881 | 931 | 1091 | 1059 | 1249 | 1122 |
| ,, | (1)......... | 1001 | 1061 | 1016 | 1053 | 935 | 1031 | 832 | 909 | 901 | 866 | 830 | 991 | 1143 | 1080 | 1203 | 1147 |
| ,, | (2)......... | 1010 | 1108 | 1037 | 1032 | 873 | 1003 | 805 | 948 | 888 | 882 | 836 | 1017 | 1154 | 1159 | 1149 | 1098 |
| ,, | (3)......... | 1034 | 1139 | 1140 | 1065 | 848 | 966 | 844 | 892 | 873 | 873 | 844 | 954 | 1156 | 1169 | 1094 | 1109 |
| March | (0)......... | 1022 | 1147 | 1172 | 1040 | 825 | 928 | 876 | 949 | 816 | 836 | 813 | 915 | 1161 | 1256 | 1099 | 1145 |
| ,, | (1)......... | 1025 | 1149 | 1175 | 1013 | 830 | 948 | 943 | 936 | 793 | 817 | 845 | 891 | 1167 | 1256 | 1106 | 1103 |
| ,, | (2)......... | 1025 | 1161 | 1168 | 968 | 885 | 949 | 946 | 897 | 781 | 827 | 852 | 915 | 1173 | 1219 | 1104 | 1129 |
| ,, | (3)......... | 988 | 1185 | 1147 | 1011 | 907 | 936 | 924 | 898 | 806 | 791 | 867 | 938 | 1138 | 1216 | 1145 | 1102 |
| April | (0)......... | 952 | 1228 | 1084 | 1059 | 881 | 972 | 876 | 879 | 847 | 765 | 932 | 946 | 1143 | 1198 | 1114 | 1126 |
| ,, | (1)......... | 940 | 1253 | 1090 | 1081 | 870 | 980 | 821 | 821 | 876 | 770 | 933 | 938 | 1162 | 1221 | 1109 | 1135 |
| ,, | (2)......... | 910 | 1259 | 1057 | 1138 | 855 | 958 | 801 | 810 | 841 | 752 | 957 | 930 | 1197 | 1284 | 1123 | 1128 |
| ,, | (3)......... | 889 | 1223 | 1056 | 1112 | 830 | 974 | 830 | 814 | 821 | 797 | 936 | 960 | 1230 | 1285 | 1134 | 1110 |
| May | (0)......... | 896 | 1180 | 1101 | 1102 | 869 | 983 | 836 | 825 | 791 | 779 | 906 | 969 | 1262 | 1279 | 1175 | 1047 |
| ,, | (1)......... | 836 | 1135 | 1124 | 1068 | 869 | 1003 | 869 | 892 | 787 | 791 | 895 | 993 | 1261 | 1290 | 1178 | 1009 |
| ,, | (2)......... | 880 | 1091 | 1150 | 1063 | 906 | 1024 | 900 | 887 | 862 | 792 | 847 | 1046 | 1256 | 1186 | 1124 | 986 |
| ,, | (3)......... | 878 | 1113 | 1190 | 1052 | 951 | 1022 | 894 | 886 | 843 | 767 | 850 | 1064 | 1222 | 1211 | 1097 | 959 |
| June | (0)......... | 886 | 1089 | 1184 | 1041 | 972 | 1024 | 917 | 894 | 875 | 773 | 844 | 1055 | 1180 | 1225 | 1096 | 947 |
| ,, | (1)......... | 902 | 1051 | 1189 | 1072 | 994 | 992 | 933 | 880 | 847 | 770 | 872 | 1072 | 1171 | 1187 | 1115 | 954 |
| ,, | (2)......... | 845 | 1078 | 1180 | 1047 | 1030 | 972 | 916 | 895 | 812 | 786 | 868 | 1081 | 1190 | 1221 | 1153 | 926 |
| ,, | (3)......... | 858 | 1053 | 1113 | 1040 | 1014 | 987 | 948 | 898 | 816 | 799 | 883 | 1073 | 1231 | 1209 | 1168 | 911 |

| | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| July | (0)........ | 892 | 1083 | 1079 | 1027 | 1007 | 965 | 931 | 866 | 780 | 817 | 880 | 1071 | 1282 | 1196 | 1177 | 948 |
| ,, | (1)........ | 911 | 1071 | 1059 | 1016 | 1016 | 947 | 920 | 856 | 810 | 815 | 849 | 1095 | 1318 | 1203 | 1168 | 947 |
| ,, | (2)........ | 982 | 1042 | 1122 | 994 | 981 | 954 | 928 | 843 | 796 | 810 | 870 | 1085 | 1266 | 1194 | 1144 | 990 |
| ,, | (3)........ | 949 | 1037 | 1141 | 1004 | 982 | 938 | 884 | 828 | 794 | 798 | 881 | 1093 | 1286 | 1203 | 1156 | 1026 |
| August | (0)........ | 930 | 1007 | 1168 | 1008 | 983 | 951 | 891 | 850 | 803 | 812 | 919 | 1090 | 1254 | 1209 | 1131 | 994 |
| ,, | (1)........ | 919 | 1058 | 1164 | 1011 | 983 | 926 | 888 | 874 | 751 | 838 | 971 | 1064 | 1206 | 1258 | 1088 | 1001 |
| ,, | (2)........ | 891 | 1104 | 1115 | 1050 | 985 | 912 | 883 | 872 | 770 | 852 | 956 | 1024 | 1228 | 1268 | 1111 | 977 |
| ,, | (3)........ | 922 | 1084 | 1101 | 1062 | 998 | 914 | 892 | 904 | 774 | 867 | 929 | 1025 | 1218 | 1239 | 1075 | 998 |
| September | (0)........ | 956 | 1118 | 1048 | 1072 | 985 | 930 | 870 | 903 | 778 | 853 | 908 | 1057 | 1230 | 1244 | 1041 | 1007 |
| ,, | (1)........ | 980 | 1129 | 1031 | 1081 | 1001 | 952 | 877 | 915 | 805 | 824 | 870 | 1060 | 1236 | 1163 | 1071 | 1004 |
| ,, | (2)........ | 1014 | 1109 | 1027 | 1040 | 985 | 974 | 864 | 947 | 789 | 808 | 894 | 1071 | 1277 | 1118 | 1061 | 1021 |
| ,, | (3)........ | 1069 | 1148 | 1005 | 981 | 959 | 961 | 839 | 948 | 819 | 801 | 929 | 1067 | 1237 | 1137 | 1098 | 1002 |
| October | (0)........ | 1052 | 1108 | 1074 | 954 | 960 | 951 | 871 | 984 | 834 | 788 | 918 | 1035 | 1225 | 1143 | 1117 | 985 |
| ,, | (1)........ | 1097 | 1102 | 1072 | 938 | 937 | 963 | 885 | 960 | 835 | 795 | 948 | 1014 | 1228 | 1180 | 1073 | 974 |
| ,, | (2)........ | 1124 | 1100 | 1070 | 925 | 953 | 946 | 916 | 936 | 839 | 820 | 971 | 1029 | 1170 | 1205 | 1070 | 926 |
| ,, | (3)........ | 1096 | 1072 | 1085 | 944 | 984 | 1001 | 928 | 934 | 866 | 813 | 927 | 1004 | 1233 | 1174 | 1036 | 903 |
| November | (0)........ | 1074 | 1094 | 1046 | 967 | 996 | 1018 | 920 | 905 | 890 | 822 | 918 | 1036 | 1220 | 1137 | 1047 | 907 |
| ,, | (1)........ | 1025 | 1060 | 1000 | 934 | 1026 | 1021 | 890 | 907 | 934 | 811 | 915 | 1058 | 1294 | 1125 | 1099 | 902 |
| ,, | (2)........ | 1003 | 1007 | 988 | 1002 | 1038 | 1052 | 868 | 909 | 1000 | 827 | 885 | 997 | 1277 | 1137 | 1109 | 903 |
| ,, | (3)........ | 939 | 1094 | 963 | 1039 | 1081 | 1076 | 872 | 900 | 981 | 795 | 906 | 1016 | 1204 | 1117 | 1150 | 865 |
| December | (0)........ | 966 | 1090 | 922 | 1042 | 1057 | 1095 | 937 | 881 | 955 | 791 | 908 | 986 | 1195 | 1172 | 1117 | 885 |
| ,, | (1)........ | 1018 | 1147 | 999 | 1082 | 1041 | 1120 | 976 | 860 | 948 | 777 | 813 | 929 | 1069 | 1236 | 1115 | 871 |
| ,, | (2)........ | 1010 | 1187 | 938 | 1057 | 1039 | 1147 | 1000 | 850 | 946 | 727 | 745 | 946 | 1124 | 1263 | 1149 | 874 |
| ,, | (3)........ | 1054 | 1185 | 966 | 1008 | 1016 | 1081 | 1040 | 821 | 899 | 749 | 684 | 971 | 1164 | 1299 | 1140 | |

5. The numbers of Table II. require to be further dealt with before they can be made to furnish a curve, bringing out the long-period variation of the declination-range. Let us first take for this purpose, as well as for other objects to be afterwards mentioned, a series of values derived from the numbers of Table II., each representing the mean of 12 consecutive values of Table II. These may be termed three-monthly values. Thus, for instance, we have as follows :—

TABLE III.—Exhibiting the Method of obtaining Three-monthly Values.

| Date, 1858. | Monthly Values for Table II. | | Three-Monthly Values. |
|---|---|---|---|
| Feb. (3) | 1034 | | |
| | | .... 983 | |
| Mar. (0) | 1022 | | .. 983 |
| | | .... 983 | |
| ,, (1) | 1025 | | |
| | | .... 980 | |
| ,, (2) | 1025 | | .. 977 |
| | | .... 974 | |
| ,, (3) | 988 | | |
| | | .... 961 | |
| Apr. (0) | 952 | | .. 955 |
| | | .... 950 | |
| ,, (1) | 940 | | |

We have thus, in the last column of Table III., a series of three-monthly values corresponding to the beginning and middle points of each month. In the next place, by adding together a certain three of these values, we may obtain nine-monthly values. Thus the three-monthly value for March (0), as above, is 983, while that for June (0) is 885, and for Sept. (0) 986 ; the mean of these (being 951) is the nine-monthly value corresponding to June (0). Nine-monthly values have thus been obtained corresponding to the beginnings of each month; and finally, by adding these together, two and two, a series of nine-monthly values have been obtained corresponding to the middle points of each month. These are given in Table IV., and a curve exhibiting them is likewise given in Fig. II. attached to this paper. Again, the numbers given by Messrs. De La Rue, Stewart, and Loewy in their paper on "Solar Physics" (Phil. Trans. 1870, page 111), exhibiting the spotted area of the sun's visible hemisphere for the years for which we have Kew declination results, have been treated in a manner precisely similar to the above; that is to say, nine-monthly values corresponding to the middle of each month have been obtained. These values are given in Table V., and a curve exhibiting them is likewise given in Fig. I. (p. 105).

TABLE IV.—Declination-range, Nine-monthly Values.

| | 1858. | 1859. | 1860. | 1861. | 1862. | 1863. | 1864. | 1865. | 1866. | 1867. | 1868. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Jan. (2) | ... | 1082 | 1109 | 1030 | 945 | 1008 | 945 | 909 | 879 | 851 | 832 |
| Feb. (2) | ... | 1090 | 1113 | 1029 | 942 | 1009 | 942 | 910 | 867 | 850 | 837 |
| Mar. (2) | ... | 1088 | 1116 | 1026 | 947 | 1006 | 934 | 907 | 850 | 844 | 846 |
| April (2) | ... | 1094 | 1117 | 1030 | 946 | 996 | 916 | 902 | 837 | 832 | 859 |
| May (2) | ... | 1105 | 1109 | 1036 | 941 | 983 | 895 | 898 | 829 | 820 | 876 |
| June (2) | 957 | 1112 | 1104 | 1032 | 942 | 971 | 887 | 894 | 826 | 811 | 891 |
| July (2) | 960 | 1112 | 1093 | 1029 | 956 | 976 | 890 | 890 | 832 | 804 | 898 |
| Aug. (2) | 962 | 1107 | 1075 | 1027 | 979 | 988 | 900 | 889 | 844 | 799 | 887 |
| Sept. (2) | 975 | 1095 | 1063 | 1016 | 1002 | 986 | 914 | 888 | 851 | 801 | 874 |
| Oct. (2) | 997 | 1092 | 1050 | 995 | 1013 | 974 | 921 | 888 | 854 | 807 | 878 |
| Nov. (2) | 1030 | 1097 | 1040 | 975 | 1010 | 962 | 918 | 888 | 852 | 816 | 885 |
| Dec. (2) | 1061 | 1102 | 1034 | 960 | 1007 | 952 | 911 | 884 | 851 | 827 | |

TABLE V.—Spotted Areas, Nine-monthly Values.

| | 1858. | 1859. | 1860. | 1861. | 1862. | 1863. | 1864. | 1865. | 1866. | 1867. |
|---|---|---|---|---|---|---|---|---|---|---|
| Jan. (2) | 504 | 1122 | 1311 | 1343 | 1112 | 913 | 770 | 598 | 522 | 72 |
| Feb. (2) | 530 | 1086 | 1220 | 1400 | 1173 | 829 | 868 | 605 | 482 | 65 |
| Mar. (2) | 538 | 1107 | 1246 | 1426 | 1249 | 745 | 943 | 574 | 438 | 55 |
| April (2) | 595 | 1241 | 1240 | 1359 | 1266 | 698 | 982 | 510 | 410 | 86 |
| May (2) | 654 | 1316 | 1244 | 1313 | 1268 | 623 | 904 | 474 | 361 | 153 |
| June (2) | 706 | 1361 | 1254 | 1333 | 1285 | 560 | 803 | 415 | 283 | 194 |
| July (2) | 778 | 1446 | 1292 | 1352 | 1249 | 515 | 766 | 366 | 198 | 211 |
| Aug. (2) | 871 | 1462 | 1357 | 1316 | 1271 | 528 | 760 | 398 | 144 | 234 |
| Sept. (2) | 983 | 1485 | 1370 | 1265 | 1294 | 606 | 823 | 461 | 120 | 251 |
| Oct. (2) | 1030 | 1532 | 1402 | 1236 | 1231 | 671 | 830 | 513 | 100 | 262 |
| Nov. (2) | 1051 | 1563 | 1437 | 1150 | 1133 | 710 | 736 | 535 | 85 | 305 |
| Dec. (2) | 1100 | 1500 | 1378 | 1077 | 1005 | 715 | 643 | 537 | 78 | |

6. If we compare together Figs. I. and II. (p. 105), it will be seen that there are a good many points in the one curve which we are fairly entitled to identify with corresponding points in the other ; of these, *b* and *i* represent the respective maximum and minimum points. There is, however, a fluctuation between *d* and *e* on the declination-curve that has no corresponding fluctuation on the sun-spot curve ; while, on the other hand, there are a series of small fluctuations on the sun-spot curve between *b* and *c* which have no distinct analogues on the declination-curve. It will, however, be seen that both of these discordant regions are represented by dotted lines on the sun-spot curve; that is to say, they represent results derived either wholly or in part from Schwabe's eye-observations while the Kew photo-heliograph was not in action.

Again, it will be remarked that each of the corresponding points occurs later in point of time in the declination than in the sun-spot curve. Thus we have :—

| | Date in Solar curve. | Date in Declination-curve. | Difference, in Months. |
|---|---|---|---|
| *a.* | Jan. 15, 1859 | July 15, 1859 | 6 |
| *b.* | Nov. 15, 1859 | Apr. 15, 1860 | 5 |
| *c.* | Dec. 15, 1861 | June 0, 1862 | $5\frac{1}{2}$ doubtful. |
| *d.* | Sept. 15, 1862 | Mar. 0, 1863 | $5\frac{1}{2}$ |
| *e.* | Aug. 0, 1863 | June 15, 1864 | $10\frac{1}{2}$ doubtful. |
| *f.* | Apr. 15, 1864 | Oct. 15, 1864 | 6 |
| *g.* | July 15, 1865 | June 0, 1866 | $10\frac{1}{2}$ |
| *h.* | Dec. 15, 1865 | Oct. 15, 1866 | 10 |
| *i.* | Mar. 15, 1867 | Aug. 15, 1867 | 5 |

I shall return again to this subject at a future part of this paper.

## C. *Lunar Annual Variation.*

7. For the purpose of discovering this variation the whole period of observation has been portioned out into lunations, beginning with new moon. Each lunation is divided into eight parts, entitled (0), (1), (2), (3), (4), (5), (6), (7); (0) denoting new, and (4) full moon.

These various lunations thus divided, with the corresponding values of the declination-range, are exhibited in Table VI., the values of which have been obtained by a method of treatment precisely similar to that adopted for the Kew temperature-ranges, and described in a previous paper (Proc. Roy. Soc. 1877, vol. xxv. p. 581).

TABLE VI.—Exhibiting the Declination-ranges grouped according to Lunations.

| Running No. | Lunation commencing new moon. | (0) | (1) | (2) | (3) | (4) | (5) | (6) | (7) |
|---|---|---|---|---|---|---|---|---|---|
| 1. | Jan. 15, 1858. | ·287 | ·322 | ·296 | ·261 | ·317 | ·437 | ·417 | ·387 |
| 2. | Feb. 13, „ | ·504 | ·470 | ·383 | ·383 | ·473 | ·557 | ·519 | ·504 |
| 3. | Mar. 15, „ | ·565 | ·609 | ·591 | ·531 | ·550 | ·622 | ·628 | ·529 |
| 4. | Apr. 13, „ | ·558 | ·606 | ·636 | ·559 | ·542 | ·465 | ·520 | ·510 |
| 5. | May 13, „ | ·488 | ·412 | ·446 | ·561 | ·578 | ·544 | ·542 | ·487 |
| 6. | June 11, „ | ·561 | ·546 | ·536 | ·439 | ·426 | ·558 | ·563 | ·536 |
| 7. | July 10, „ | ·572 | ·616 | ·539 | ·568 | ·617 | ·615 | ·534 | ·462 |
| 8. | Aug. 9, „ | ·537 | ·570 | ·556 | ·541 | ·552 | ·582 | ·575 | ·500 |
| 9. | Sept. 7, „ | ·526 | ·633 | ·595 | ·531 | ·486 | ·537 | ·613 | ·602 |
| 10. | Oct. 7, „ | ·506 | ·499 | ·508 | ·539 | ·580 | ·524 | ·522 | ·480 |
| 11. | Nov. 5, „ | ·415 | ·362 | ·417 | ·404 | ·337 | ·382 | ·375 | ·276 |
| 12. | Dec. 5, „ | ·220 | ·289 | ·367 | ·367 | ·351 | ·374 | ·319 | ·286 |
| 13. | Jan. 4, 1859. | ·289 | ·348 | ·364 | ·366 | ·387 | ·294 | ·293 | ·368 |
| 14. | Feb. 3, „ | ·387 | ·482 | ·471 | ·426 | ·479 | ·500 | ·493 | ·511 |
| 15. | Mar. 4, „ | ·555 | ·569 | ·624 | ·645 | ·664 | ·704 | ·676 | ·742 |
| 16. | Apr. 3, „ | ·742 | ·746 | ·867 | ·914 | ·894 | ·819 | ·766 | ·711 |
| 17. | May 2, „ | ·603 | ·613 | ·621 | ·655 | ·670 | ·640 | ·570 | ·622 |
| 18. | June 1, „ | ·736 | ·710 | ·667 | ·625 | ·607 | ·576 | ·647 | ·694 |
| 19. | June 30, „ | ·740 | ·662 | ·561 | ·656 | ·681 | ·537 | ·537 | ·599 |
| 20. | July 29, „ | ·646 | ·685 | ·599 | ·586 | ·638 | ·652 | ·697 | ·739 |
| 21. | Aug. 28, „ | ·753 | ·616 | ·547 | ·652 | ·646 | ·670 | ·631 | ·611 |

TABLE VI. (*continued*).

| Running No. | Lunation commencing new moon. | (0) | (1) | (2) | (3) | (4) | (5) | (6) | (7) |
|---|---|---|---|---|---|---|---|---|---|
| 22. | Sept. 26, 1859. | ·603 | ·621 | ·558 | ·520 | ·472 | ·503 | ·548 | ·532 |
| 23. | Oct. 26, „ | ·549 | ·475 | ·413 | ·451 | ·464 | ·433 | ·392 | ·370 |
| 24. | Nov. 24, „ | ·340 | ·332 | ·388 | ·412 | ·386 | ·378 | ·345 | ·366 |
| 25. | Dec. 24, „ | ·317 | ·317 | ·402 | ·450 | ·365 | ·315 | ·347 | ·398 |
| 26. | Jan. 23, 1860. | ·442 | ·403 | ·359 | ·342 | ·382 | ·467 | ·435 | ·445 |
| 27. | Feb. 21, „ | ·458 | ·461 | ·533 | ·590 | ·633 | ·709 | ·662 | ·594 |
| 28. | Mar. 22, „ | ·662 | ·661 | ·617 | ·720 | ·720 | ·643 | ·719 | ·716 |
| 29. | Apr. 21, „ | ·684 | ·625 | ·598 | ·597 | ·677 | ·660 | ·639 | ·688 |
| 30. | May 20, „ | ·687 | ·663 | ·624 | ·659 | ·788 | ·822 | ·690 | ·686 |
| 31. | June 19, „ | ·738 | ·684 | ·629 | ·573 | ·634 | ·652 | ·594 | ·546 |
| 32. | July 18, „ | ·617 | ·760 | ·772 | ·786 | ·738 | ·677 | ·613 | ·648 |
| 33. | Aug. 16, „ | ·700 | ·701 | ·668 | ·700 | ·697 | ·614 | ·492 | ·486 |
| 34. | Sept. 15, „ | ·504 | ·568 | ·620 | ·573 | ·521 | ·470 | ·518 | ·539 |
| 35. | Oct. 14, „ | ·586 | ·527 | ·483 | ·522 | ·509 | ·460 | ·446 | ·419 |
| 36. | Nov. 13, „ | ·400 | ·367 | ·319 | ·323 | ·380 | ·359 | ·272 | ·293 |
| 37. | Dec. 12, „ | ·274 | ·303 | ·353 | ·318 | ·244 | ·243 | ·321 | ·295 |
| 38. | Jan. 11, 1861. | ·300 | ·297 | ·361 | ·395 | ·417 | ·390 | ·395 | ·362 |
| 39. | Feb. 9, „ | ·417 | ·418 | ·466 | ·511 | ·448 | ·452 | ·518 | ·511 |
| 40. | Mar. 11, „ | ·524 | ·511 | ·576 | ·468 | ·485 | ·670 | ·760 | ·781 |
| 41. | Apr. 10, „ | ·765 | ·703 | ·712 | ·709 | ·714 | ·683 | ·627 | ·639 |
| 42. | May 9, „ | ·638 | ·596 | ·557 | ·551 | ·586 | ·622 | ·632 | ·659 |
| 43. | June 8, „ | ·655 | ·634 | ·638 | ·668 | ·690 | ·584 | ·565 | ·617 |
| 44. | July 8, „ | ·637 | ·597 | ·563 | ·621 | ·604 | ·555 | ·559 | ·593 |
| 45. | Aug. 6, „ | ·684 | ·631 | ·565 | ·624 | ·671 | ·718 | ·644 | ·615 |
| 46. | Sept. 4, „ | ·653 | ·628 | ·569 | ·601 | ·599 | ·538 | ·449 | ·392 |
| 47. | Oct. 4, „ | ·436 | ·450 | ·425 | ·478 | ·526 | ·466 | ·394 | ·388 |
| 48. | Nov. 2, „ | ·374 | ·410 | ·439 | ·406 | ·405 | ·374 | ·386 | ·347 |
| 49. | Dec. 2, „ | ·354 | ·371 | ·343 | ·318 | ·330 | ·318 | ·281 | ·288 |
| 50, | Dec. 31, „ | ·335 | ·302 | ·252 | ·374 | ·345 | ·308 | ·328 | ·319 |
| 51, | Jan. 30, 1862. | ·358 | ·370 | ·394 | ·408 | ·374 | ·374 | ·343 | ·275 |
| 52, | Feb. 28, „ | ·314 | ·412 | ·478 | ·473 | ·484 | ·512 | ·500 | ·525 |
| 53. | Mar. 30, „ | ·553 | ·588 | ·539 | ·480 | ·577 | ·548 | ·501 | ·484 |
| 54. | Apr. 28, „ | ·552 | ·498 | ·511 | ·522 | ·533 | ·497 | ·477 | ·553 |
| 55. | May 28, „ | ·579 | ·626 | ·622 | ·587 | ·631 | ·583 | ·568 | ·629 |
| 56. | June 27, „ | ·692 | ·637 | ·562 | ·558 | ·578 | ·635 | ·610 | ·537 |
| 57. | July 26, „ | ·576 | ·582 | ·557 | ·567 | ·558 | ·623 | ·623 | ·604 |
| 58. | Aug. 25, „ | ·646 | ·635 | ·588 | ·582 | ·522 | ·527 | ·519 | ·570 |
| 59. | Sept. 23, „ | ·578 | ·522 | ·450 | ·442 | ·407 | ·446 | ·492 | ·448 |
| 60. | Oct. 23, „ | ·445 | ·483 | ·460 | ·414 | ·448 | ·394 | ·395 | ·422 |
| 61. | Nov. 21, „ | ·390 | ·383 | ·377 | ·382 | ·370 | ·297 | ·292 | ·273 |
| 62. | Dec. 21, „ | ·305 | ·337 | ·314 | ·300 | ·388 | ·438 | ·429 | ·404 |
| 63. | Jan. 19, 1863. | ·347 | ·321 | ·413 | ·434 | ·423 | ·454 | ·400 | ·345 |
| 64. | Feb. 18, „ | ·385 | ·430 | ·443 | ·446 | ·453 | ·459 | ·445 | ·497 |
| 65. | Mar. 19, „ | ·566 | ·600 | ·589 | ·608 | ·580 | ·552 | ·625 | ·654 |
| 66. | Apr. 18, „ | ·678 | ·630 | ·573 | ·547 | ·521 | ·580 | ·586 | ·615 |
| 67. | May 17, „ | ·663 | ·621 | ·612 | ·572 | ·606 | ·581 | ·566 | ·629 |
| 68. | June 16, „ | ·634 | ·595 | ·538 | ·575 | ·599 | ·610 | ·617 | ·573 |
| 69. | July 15, „ | ·549 | ·533 | ·492 | ·551 | ·590 | ·577 | ·584 | ·590 |
| 70. | Aug. 14, „ | ·580 | ·454 | ·474 | ·538 | ·578 | ·561 | ·569 | ·581 |
| 71. | Sept. 13, „ | ·590 | ·538 | ·502 | ·515 | ·497 | ·487 | ·448 | ·451 |
| 72. | Oct. 12, „ | ·497 | ·469 | ·467 | ·480 | ·418 | ·455 | ·478 | ·457 |
| 73. | Nov. 11, „ | ·443 | ·411 | ·376 | ·340 | ·321 | ·355 | ·418 | ·430 |
| 74. | Dec. 10, „ | ·422 | ·340 | ·314 | ·341 | ·298 | ·327 | ·319 | ·317 |
| 75. | Jan. 9, 1864. | ·265 | ·278 | ·374 | ·380 | ·332 | ·358 | ·323 | ·300 |
| 76. | Feb. 7, „ | ·325 | ·371 | ·382 | ·297 | ·293 | ·360 | ·406 | ·427 |
| 77. | Mar. 8, „ | ·528 | ·550 | ·534 | ·576 | ·589 | ·516 | ·477 | ·516 |

TABLE VI. (*continued*).

| Running No. | Lunation commencing new moon. | (0) | (1) | (2) | (3) | (4) | (5) | (6) | (7) |
|---|---|---|---|---|---|---|---|---|---|
| 78. | Apr. 6, 1864. | ·587 | ·557 | ·500 | ·468 | ·518 | ·478 | ·507 | ·536 |
| 79. | May 6, „ | ·523 | ·491 | ·469 | ·479 | ·504 | ·548 | ·520 | ·571 |
| 80. | June 4, „ | ·572 | ·598 | ·563 | ·557 | ·584 | ·556 | ·505 | ·540 |
| 81. | July 4, „ | ·628 | ·583 | ·523 | ·510 | ·553 | ·522 | ·486 | ·494 |
| 82. | Aug. 2, „ | ·497 | ·544 | ·526 | ·567 | ·600 | ·548 | ·520 | ·546 |
| 83. | Sept. 1, „ | ·531 | ·542 | ·471 | ·433 | ·452 | ·519 | ·456 | ·407 |
| 84. | Sept. 30, „ | ·439 | ·406 | ·436 | ·422 | ·443 | ·483 | ·490 | ·441 |
| 85. | Oct. 30, „ | ·403 | ·369 | ·346 | ·368 | ·385 | ·370 | ·296 | ·275 |
| 86. | Nov. 29, „ | ·269 | ·286 | ·311 | ·341 | ·366 | ·315 | ·325 | ·309 |
| 87. | Dec. 28, „ | ·247 | ·212 | ·329 | ·387 | ·326 | ·303 | ·357 | ·335 |
| 88. | Jan. 27, 1865. | ·364 | ·348 | ·384 | ·424 | ·314 | ·358 | ·390 | ·425 |
| 89. | Feb. 25, „ | ·484 | ·470 | ·400 | ·408 | ·513 | ·531 | ·515 | ·550 |
| 90. | Mar. 27, „ | ·559 | ·533 | ·531 | ·564 | ·561 | ·476 | ·414 | ·485 |
| 91. | Apr. 25, „ | ·563 | ·556 | ·509 | ·442 | ·523 | ·539 | ·526 | ·521 |
| 92. | May 24, „ | ·512 | ·493 | ·492 | ·535 | ·559 | ·588 | ·565 | ·499 |
| 93. | June 23, „ | ·543 | ·552 | ·539 | ·514 | ·479 | ·495 | ·478 | ·489 |
| 94. | July 22, „ | ·530 | ·504 | ·492 | ·473 | ·542 | ·553 | ·539 | ·567 |
| 95. | Aug. 21, „ | ·568 | ·509 | ·529 | ·502 | ·557 | ·548 | ·500 | ·520 |
| 96. | Sept. 19, „ | ·528 | ·513 | ·516 | ·480 | ·463 | ·486 | ·496 | ·454 |
| 97. | Oct. 19, „ | ·423 | ·443 | ·409 | ·387 | ·376 | ·440 | ·393 | ·356 |
| 98. | Nov. 18, „ | ·303 | ·346 | ·310 | ·295 | ·305 | ·285 | ·277 | ·224 |
| 99. | Dec. 18, „ | ·230 | ·244 | ·243 | ·274 | ·263 | ·234 | ·317 | ·376 |
| 100. | Jan. 16, 1866. | ·329 | ·308 | ·315 | ·332 | ·313 | ·333 | ·378 | ·426 |
| 101. | Feb. 15, „ | ·399 | ·346 | ·349 | ·372 | ·359 | ·399 | ·471 | ·410 |
| 102. | Mar. 16, „ | ·395 | ·415 | ·460 | ·450 | ·528 | ·580 | ·579 | ·614 |
| 103. | Apr. 15, „ | ·638 | ·569 | ·490 | ·396 | ·437 | ·498 | ·382 | ·435 |
| 104. | May 14, „ | ·516 | ·538 | ·507 | ·511 | ·515 | ·474 | ·482 | ·547 |
| 105. | June 12, „ | ·606 | ·560 | ·455 | ·442 | ·505 | ·463 | ·429 | ·434 |
| 106. | July 12, „ | ·498 | ·543 | ·519 | ·477 | ·445 | ·444 | ·438 | ·488 |
| 107. | Aug. 10, „ | ·503 | ·473 | ·427 | ·449 | ·489 | ·479 | ·480 | ·452 |
| 108. | Sept. 9, „ | ·477 | ·453 | ·440 | ·402 | ·428 | ·416 | ·372 | ·447 |
| 109. | Oct. 8, „ | ·472 | ·460 | ·445 | ·365 | ·334 | ·332 | ·353 | ·442 |
| 110. | Nov. 7, „ | ·448 | ·427 | ·389 | ·349 | ·296 | ·309 | ·388 | ·314 |
| 111. | Dec. 7, „ | ·296 | ·305 | ·324 | ·319 | ·219 | ·233 | ·289 | ·217 |
| 112. | Jan. 6, 1867. | ·309 | ·349 | ·358 | ·343 | ·288 | ·238 | ·241 | ·294 |
| 113. | Feb. 4, „ | ·346 | ·419 | ·442 | ·395 | ·356 | ·311 | ·358 | ·397 |
| 114. | Mar. 6, „ | ·400 | ·477 | ·500 | ·443 | ·447 | ·466 | ·487 | ·496 |
| 115. | Apr. 4, „ | ·446 | ·395 | ·483 | ·534 | ·547 | ·477 | ·472 | ·515 |
| 116. | May 4, „ | ·503 | ·429 | ·385 | ·400 | ·514 | ·443 | ·384 | ·503 |
| 117. | June 2, „ | ·508 | ·468 | ·396 | ·469 | ·521 | ·507 | ·509 | ·465 |
| 118. | July 1, „ | ·508 | ·512 | ·430 | ·473 | ·481 | ·500 | ·455 | ·457 |
| 119. | July 31, „ | ·504 | ·486 | ·470 | ·519 | ·547 | ·583 | ·550 | ·528 |
| 120. | Aug. 29, „ | ·543 | ·493 | ·484 | ·431 | ·453 | ·485 | ·420 | ·401 |
| 121. | Sept. 27, „ | ·424 | ·431 | ·387 | ·348 | ·339 | ·418 | ·426 | ·410 |
| 122. | Oct. 27, „ | ·408 | ·349 | ·341 | ·298 | ·309 | ·361 | ·304 | ·314 |
| 123. | Nov. 26, „ | ·358 | ·247 | [·212] | [·237] | ·233 | ·208 | ·237 | ·222 |
| 124. | Dec. 26, „ | ·224 | ·245 | ·231 | ·242 | [·254] | [·266] | ·277 | ·323 |
| 125. | Jan. 24, 1868. | ·361 | ·319 | ·293 | ·369 | ·376 | ·348 | ·318 | ·336 |
| 126. | Feb. 23, „ | ·426 | ·391 | ·392 | ·421 | ·419 | ·398 | ·464 | ·504 |
| 127. | Mar. 24, „ | ·556 | ·538 | ·545 | ·588 | ·640 | ·646 | ·626 | ·550 |
| 128. | Apr. 22, „ | ·580 | ·636 | ·557 | ·487 | ·502 | ·507 | ·489 | ·473 |
| 129. | May 22, „ | ·495 | ·524 | ·468 | ·450 | ·553 | ·536 | ·516 | ·558 |
| 130. | June 20, „ | ·563 | ·515 | ·509 | ·512 | ·539 | ·508 | ·497 | ·487 |
| 131. | July 19, „ | ·493 | ·548 | ·516 | ·532 | ·573 | ·594 | ·584 | ·616 |
| 132. | Aug. 18, „ | ·671 | ·603 | ·548 | ·511 | ·480 | ·512 | ·530 | ·488 |
| 133. | Sept. 16, „ | ·452 | ·480 | ·533 | ·504 | ·463 | ·493 | ·442 | ·384 |

TABLE VI. (*continued*).

| Running No. | Lunation commencing new moon. | (0) | (1) | (2) | (3) | (4) | (5) | (6) | (7) |
|---|---|---|---|---|---|---|---|---|---|
| 134. | Oct. 15, 1868. | ·437 | ·498 | ·474 | ·491 | ·391 | ·353 | ·384 | ·310 |
| 135. | Nov. 14, " | ·295 | ·351 | ·384 | ·353 | ·253 | ·239 | ·258 | ·276 |
| 136. | Dec. 14, " | ·240 | ·213 | ·186 | ·205 | ·200 | ·181 | ·197 | ·275 |
| 137. | Jan. 12, 1869. | ·258 | ·212 | ·239 | ·215 | ·283 | ·327 | ·417 | ·492 |
| 138. | Feb. 11, " | ·501 | ·417 | ·400 | ·412 | ·399 | ·351 | ·419 | ·521 |
| 139. | Mar. 13, " | ·527 | ·467 | ·476 | ·586 | ·586 | ·560 | ·578 | ·611 |
| 140. | Apr. 12, " | ·666 | ·591 | ·538 | ·530 | ·582 | ·609 | ·584 | ·616 |
| 141. | May 11, " | ·623 | ·588 | ·521 | ·509 | ·624 | ·689 | ·682 | ·711 |
| 142. | June 10, " | ·602 | ·561 | ·601 | ·653 | ·704 | ·713 | ·684 | ·655 |
| 143. | July 9, " | ·612 | ·593 | ·619 | ·643 | ·690 | ·679 | ·661 | ·668 |
| 144. | Aug. 7, " | ·656 | ·601 | ·591 | ·619 | ·646 | ·635 | ·593 | ·668 |
| 145. | Sept. 6, " | ·667 | ·640 | ·622 | ·565 | ·550 | ·565 | ·496 | ·529 |
| 146. | Oct. 5, " | ·575 | ·522 | ·477 | ·436 | ·441 | ·504 | ·496 | ·475 |
| 147. | Nov. 3, " | ·439 | ·443 | ·475 | ·392 | ·359 | ·378 | ·304 | ·258 |
| 148. | Dec. 3, " | ·320 | ·367 | ·339 | ·311 | ·234 | ·218 | ·245 | ·290 |
| 149. | Jan. 2, 1870. | ·344 | ·316 | ·294 | ·269 | ·284 | ·345 | ·380 | ·374 |
| 150. | Jan. 31, " | ·414 | ·475 | ·518 | ·488 | ·461 | ·500 | ·483 | ·453 |
| 151. | Mar. 2, " | ·535 | ·592 | ·644 | ·649 | ·651 | ·709 | ·690 | ·659 |
| 152. | Apr. 1, " | ·742 | ·704 | ·811 | ·775 | ·741 | ·811 | ·790 | ·786 |
| 153. | Apr. 30, " | ·745 | ·665 | ·714 | ·753 | ·761 | ·702 | ·692 | ·738 |
| 154. | May 30, " | ·732 | ·692 | ·619 | ·643 | ·759 | ·806 | ·715 | ·751 |
| 155. | June 28, " | ·840 | ·742 | ·709 | ·826 | ·823 | ·852 | ·790 | ·695 |
| 156. | July 28, " | ·659 | ·696 | ·776 | ·745 | ·722 | ·799 | ·719 | ·681 |
| 157. | Aug. 26, " | ·739 | ·766 | ·750 | ·713 | ·720 | ·729 | ·637 | ·652 |
| 158. | Sept. 25, " | ·721 | ·704 | ·614 | ·547 | ·570 | ·589 | ·601 | ·562 |
| 159. | Oct. 24, " | ·470 | ·586 | ·611 | ·571 | ·509 | ·528 | ·590 | ·559 |
| 160. | Nov. 23, " | ·418 | ·375 | ·325 | ·335 | ·343 | ·390 | ·363 | ·312 |
| 161. | Dec. 22, " | ·339 | ·335 | ·373 | ·361 | ·367 | ·360 | ·372 | ·357 |
| 162. | Jan. 21, 1871. | ·372 | ·359 | ·378 | ·461 | ·471 | ·442 | ·419 | ·495 |
| 163. | Feb. 19, " | ·489 | ·557 | ·582 | ·582 | ·603 | ·682 | ·735 | ·712 |
| 164. | Mar. 21, " | ·679 | ·680 | ·673 | ·690 | ·812 | ·823 | ·797 | ·758 |
| 165. | Apr. 19, " | ·819 | ·852 | ·887 | ·814 | ·671 | ·629 | ·650 | ·779 |
| 166. | May 19, " | ·747 | ·600 | ·583 | ·717 | ·793 | ·855 | ·773 | ·750 |
| 167. | June 18, " | ·699 | ·635 | ·716 | ·751 | ·762 | ·673 | ·677 | ·738 |
| 168. | July 17, " | ·748 | ·634 | ·589 | ·704 | ·767 | ·761 | ·722 | ·737 |
| 169. | Aug. 16, " | ·841 | ·829 | ·797 | ·748 | ·702 | ·684 | ·713 | ·663 |
| 170. | Sept. 14, " | ·679 | ·678 | ·495 | ·476 | ·583 | ·626 | ·638 | ·625 |
| 171. | Oct. 14, " | ·625 | ·617 | ·559 | ·489 | ·504 | ·512 | ·449 | ·421 |
| 172. | Nov. 12, " | ·478 | ·493 | ·432 | ·419 | ·396 | ·333 | ·359 | ·434 |
| 173. | Dec. 12, " | ·445 | ·449 | ·422 | ·396 | ·318 | ·364 | ·358 | ·412 |
| 174. | Jan. 10, 1872. | ·392 | ·431 | ·478 | ·475 | ·496 | ·504 | ·484 | ·478 |
| 175. | Feb. 9, " | ·482 | ·508 | ·484 | ·446 | ·478 | ·474 | ·467 | ·501 |
| 176. | Mar. 9, " | ·584 | ·628 | ·628 | ·671 | ·664 | ·632 | ·728 | ·741 |
| 177. | Apr. 8, " | ·733 | ·704 | ·668 | ·724 | ·763 | ·732 | ·625 | ·678 |
| 178. | May 7, " | ·719 | ·679 | ·671 | ·604 | ·611 | ·621 | ·590 | ·610 |
| 179. | June 6, " | ·723 | ·753 | ·671 | ·692 | ·759 | ·704 | ·671 | ·678 |
| 180. | July 5, " | ·679 | ·744 | ·735 | ·731 | ·684 | ·608 | ·588 | ·649 |
| 181. | Aug. 4, " | ·728 | ·729 | ·684 | ·615 | ·646 | ·621 | ·639 | ·686 |
| 182. | Sept. 3, " | ·629 | ·609 | ·568 | ·560 | ·608 | ·609 | ·572 | ·561 |
| 183. | Oct. 2, " | ·591 | ·608 | ·524 | ·466 | ·428 | ·455 | ·483 | ·489 |
| 184. | Nov. 1, " | ·507 | ·459 | ·459 | ·440 | ·432 | ·432 | ·391 | ·393 |
| 185. | Nov. 30, " | ·411 | ·405 | ·338 | ·302 | ·329 | ·349 | ·365 | ·347 |
| 186. | Dec. 30, " | ·355 | ·413 | ·376 | ·377 | ·419 | ·411 | ·386 | ·459 |
| 187. | Jan. 28, 1873. | ·447 | ·467 | ·476 | ·413 | ·407 | ·446 | ·494 | ·456 |
| 188. | Feb. 27, " | ·520 | ·571 | ·532 | ·580 | ·597 | ·583 | ·623 | ·712 |
| 189. | Mar. 28, " | ·706 | ·658 | ·693 | ·795 | ·791 | ·694 | ·710 | ·729 |

TABLE VI. (*continued*).

| Running No. | Lunation commencing new moon. | (0) | (1) | (2) | (3) | (4) | (5) | (6) | (7) |
|---|---|---|---|---|---|---|---|---|---|
| 190. | Apr. 26, 1873. | ·733 | ·599 | ·568 | ·547 | ·548 | ·575 | ·516 | ·559 |
| 191. | May 26, " | ·627 | ·616 | ·560 | ·519 | ·547 | ·568 | ·593 | ·585 |
| 192. | June 24, " | ·567 | ·556 | ·529 | ·530 | ·625 | ·628 | ·524 | ·561 |
| 193. | July 24, " | ·649 | ·651 | ·566 | ·622 | ·612 | ·575 | ·575 | ·602 |
| 194. | Aug. 23, " | ·599 | ·614 | ·627 | ·608 | ·606 | ·578 | ·539 | ·520 |
| 195. | Sept. 21, " | ·570 | ·578 | ·534 | ·513 | ·477 | ·478 | ·424 | ·393 |
| 196. | Oct. 21, " | ·465 | ·417 | ·411 | ·411 | ·383 | ·336 | ·385 | ·349 |
| 197. | Nov. 20, " | ·315 | ·375 | ·323 | ·236 | ·223 | [·243] | [·263] | ·282 |

8. Making use of the whole series of lunations of Table VI. we obtain the following results:—

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Phase of lunation... | (0) | (1) | (2) | (3) | (4) | (5) | (6) | (7) | |
| Value of range...... | ·519 | ·512 | ·499 | ·499 | ·507 | ·508 | ·499 | ·503 | (A) |

a series which presents the appearance of a double period with maxima about new and full moon. A similar result has been obtained for Lisbon by Senhor Capello, Director of the observatory there ('Annals of the Observatory,' 1876), who finds that the declination-ranges, or rather the differences of the declination at 8 A.M. and at 2 P.M., obey a law similar to that stated above.

It may likewise be remarked (as was done in the corresponding discussion of temperate-ranges) that the sum of the four left-hand numbers is larger than that of the four right-hand numbers—the former being 2·029, while the latter is 2·017.

## D. *Semiannual Lunar Variation.*

9. If we now make use of the lunations corresponding to the six months of which the middle point is the winter solstice, employing for this purpose lunations 1–2, 9–15, 22–27, 34–39, 47–52, 59–64, 71–76, 84–89, 96–101, 108–114, 121–126, 133–138, 146–151, 158–163, 170–175, 183–188, 195–197 (in all 97 lunations) we obtain the following result:—

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Phase of lunation... | (0) | (1) | (2) | (3) | (4) | (5) | (6) | (7) | |
| Value of winter range........... | ·415 | ·420 | ·415 | ·408 | ·401 | ·409 | ·413 | ·412 | (B) |

But before making use of these numbers we must apply to them a small correction. For it is possible that the sum of the various new-moon observations for any six winter months, inasmuch as they occur at dates preceding those of the corresponding full-moon observations, or observations for other phases, may be affected differently from the latter by the annual variation indicated in Table I. A correction on this account

has therefore been obtained from Table I., and when applied to (B) we obtain the following result:—

| Phase of lunation... | (0) | (1) | (2) | (3 | (4) | (5) | (6) | (7) | |
|---|---|---|---|---|---|---|---|---|---|
| Corrected value of winter range...... | ·417 | ·422 | ·416 | ·409 | ·402 | ·409 | ·411 | ·408 | (C) |

Series (C) is represented in Fig. XI. (p. 120).

10. If we now make use of the observations corresponding to the six months grouped around the summer solstice (100 in all), we obtain the following results:—

| Phase of lunation... | (0) | (1) | (2) | (3) | (4) | (5) | (6) | (7) | |
|---|---|---|---|---|---|---|---|---|---|
| Value of summer range............ | ·621 | ·601 | ·580 | ·587 | ·610 | ·604 | ·582 | ·591 | (D) |

and if we apply to this a residual correction analogous to that applied to (B), we obtain as follows:—

| Phase of lunation... | (0) | (1) | (2) | (3) | (4) | (5) | (6) | (7) | |
|---|---|---|---|---|---|---|---|---|---|
| Corrected value of summer range. | ·620 | ·600 | ·578 | ·586 | ·609 | ·604 | ·584 | ·596 | (E) |

In series (E) we have well-marked maxima corresponding to new and to full moon.

### E. *Variations which seem to depend on Planetary Configurations.*

11. From art. 6 we may conclude that the connexion between solar spotted areas and declination-ranges is an intimate one. Now Messrs. De La Rue, Stewart, and Loewy, in a paper already quoted (Phil. Trans. 1870), have shown that the amount of spotted area of the sun's surface exhibits a reference to the chief planetary configurations. It becomes, therefore, a question of interest to ask whether declination-ranges exhibit a reference of the same kind*.

In order to reply to this I have selected those configurations which occur most frequently, and which might therefore be supposed to be sufficiently well indicated by sixteen years' observations.

These are, ($\alpha$) the period of conjunction of Venus and Mercury, ($\beta$) the solar period of Mercury, ($\gamma$) the period of conjunction of Venus and Jupiter.

In the next place, three-monthly values for every week have been constructed after the manner indicated in Table III. Now inasmuch as the periods of the three configurations already alluded to are not very far different from three months, we may imagine that these three-monthly values are to a great extent free from any inequality depending on these periods. The differences between the monthly and the three-monthly values will, however, exhibit any such inequality as may exist. These

* Mr. C. Chambers, of the Bombay Observatory, has discussed the question as to whether certain other magnetic elements have a reference of this kind (Phil. Trans. 1875, p. 361).

differences, slightly equalized, are therefore made to form the ordinates of a curve of which the time is the abscissa, and we may expect to derive from such a curve materials for determining whether there be any inequality in the declination-range due to such configurations. The method employed in plotting this curve will be understood from the following example :—

TABLE VII.

| Date, 1858. | Monthly value. | Three-monthly value. | Difference. | Final equalized difference, plotted in the curve. |
|---|---|---|---|---|
| Feb. (3) | 1034 | | | |
| | | .... 983 | .... +45 | |
| Mar. (0) | 1022 | | | +43 |
| | | .... 983 | .... +40 | |
| ,, (1) | 1025 | | | +42 |
| | | .... 980 | .... +45 | |
| ,, (2) | 1025 | | | +38 |
| | | .... 974 | .... +32 | |
| ,, (3) | 988 | | | +21 |
| | | .... 961 | .... + 9 | |
| April (0) | 952 | | | + 2 |
| | | .... 950 | .... − 4 | |
| ,, (1) | 940 | | | |

12. With regard to the first configuration mentioned (the period of conjunction of Venus and Mercury), these observations embrace 39 periods in all; and summing up the ordinates of the curve corresponding to each 30 degrees of angular separation for the various 39 periods, precisely after the manner employed in the paper on Solar Physics already referred to, we obtain the following result:—

TABLE VIII.—Venus and Mercury together (0° denotes conjunction).

| | | | | |
|---|---|---|---|---|
| Between | 0° | and | 30° | +193 |
| ,, | 30 | ,, | 60 | + 23 |
| ,, | 60 | ,, | 90 | −196 |
| ,, | 90 | ,, | 120 | −207 |
| ,, | 120 | ,, | 150 | − 93 |
| ,, | 150 | ,, | 180 | − 59 |
| ,, | 180 | ,, | 210 | − 43 |
| ,, | 210 | ,, | 240 | + 13 |
| ,, | 240 | ,, | 270 | + 26 |
| ,, | 270 | ,, | 300 | − 52 |
| ,, | 300 | ,, | 330 | − 49 |
| ,, | 330 | ,, | 360 | 119 |

In Figs. III. and IV. (p. 105) the sun-spot and the declination-curve for this configuration are exhibited together. It will be noticed that there is a very striking likeness between the two, the declination-curve, however,

lagging behind the other in point of time, as might be expected from art. 6.

13. Next with regard to the second configuration (the solar period of Mercury), the results are so decided that half the declination observations are sufficient to give a tolerably good value. This will be seen from the following Table :—

TABLE IX.—Period of Mercury about the Sun (in all 65 sets : 0° denotes Perihelion).

| | First half. | Second half. | Whole series. |
|---|---|---|---|
| Between 0° and 30° | +217 | +212 | +429 |
| „ 30 „ 60 | +153 | +280 | +433 |
| „ 60 „ 90 | − 3 | +259 | +256 |
| „ 90 „ 120 | −168 | +173 | + 5 |
| „ 120 „ 150 | −281 | + 1 | −280 |
| „ 150 „ 180 | −276 | −163 | −439 |
| „ 180 „ 210 | −151 | −262 | −413 |
| „ 210 „ 240 | − 5 | −274 | −279 |
| „ 240 „ 270 | + 73 | −213 | −140 |
| „ 270 „ 300 | +114 | −101 | + 13 |
| „ 300 „ 330 | +145 | + 13 | +158 |
| „ 330 „ 360 | +181 | + 97 | +278 |

In Figs. V. and VI. the supposed inequalities due to this period are compared together for spotted solar area and declination-range. It will be observed that the latter lags visibly behind the former in point of time.

14. Let us, in the last place, consider the period of the conjunction of Jupiter and Mercury. In this case, as in the previous one, the inequality is so well marked that the observations may be split into two series ; this will be seen from the following Table :—

TABLE X.—Period of Conjunction of Mercury and Jupiter (in all 63 sets : 0° denotes conjunction).

| | First half. | Second half. | Whole series. |
|---|---|---|---|
| Between 0° and 30° | +198 | +435 | +633 |
| „ 30 „ 60 | +236 | +523 | +759 |
| „ 60 „ 90 | +225 | +427 | +652 |
| „ 90 „ 120 | +119 | +209 | +328 |
| „ 120 „ 150 | − 46 | − 73 | −119 |
| „ 150 „ 180 | −185 | −319 | −504 |
| „ 180 „ 210 | −251 | −427 | −678 |
| „ 210 „ 240 | −230 | −447 | −677 |
| „ 240 „ 270 | −157 | −391 | −548 |
| „ 270 „ 300 | − 91 | −231 | −322 |
| „ 300 „ 330 | 0 | − 10 | − 10 |
| „ 330 „ 360 | +118 | +225 | +343 |

In Figs. VII. and VIII. the supposed inequalities due to the above period are compared together for solar spotted area and declination-range. It will be noticed that the latter lags visibly behind the former in point of time.

F. *Remarks on the supposed relations between Solar spotted areas, Declination-ranges, and Temperature-ranges.*

15. A few remarks on this subject will not be considered unallowable if the object be not so much to introduce a final theory as to suggest a working hypothesis which, while not inconsistent with any well-established fact, may perhaps serve to direct future inquiry.

In the first place, we may conclude, as the result of the comparison of Figs. I. and II., that the connexion between spotted areas and declination-ranges is of an intimate nature, the smaller inequalities of the one being reproduced in the other with modifications.

16. In the next place, it seems almost certain that sun-spots are not the chief cause of magnetic action. Mr. Broun, in a recent paper "On the Decennial Period in the Range and Disturbance of the Diurnal Oscillations of the Magnetic Needle and in Sun-spot area" (Trans. Roy. Soc. Edinb. 1876), has made a remark similar to the above, founding it upon the fact that sun-spots appear only when the magnetic action exceeds a given value.

17. Nevertheless it is most probable that magnetic activity is somehow caused by the sun, depending perhaps on the physical state of his surface, while sun-spots give us only a rough mode of estimating this physical state, just as rainfall might in estimating the climate of a place. For it will be seen that the effect of the sun upon magnetic range bears all the appearances of being due to an influence *emanating* from our luminary. For just as the maxima of yearly and daily temperature lag behind the corresponding maxima of solar heat influence, so do the maxima and minima of declination-range lag behind the corresponding maxima and minima in the solar curve, while the same lagging behind appears in the curves, denoting the supposed influence of the planets on the state of the solar surface and (through it?) on the magnetic range.

18. Again, we may probably imagine that sun-spots give us a roughly true indication of solar activity; for if this were not so it would be difficult to account for the striking likeness between the sun-spot planetary curves and the declination-range planetary curves. That the sun-spots afford but a rough indication of the physical state of the sun will of course be gathered from the fact that the sun is influential both in meteorology and magnetism when there are no spots; and the same conclusion appears to be supported by the fact that the planetary inequalities appear to be more pronounced when derived from declination-ranges than when derived from sun-spots.

19. There seems, however, to be something more than this; there

appears to be in the march of the declination-range from year to year (Fig. II.) traces of a force which prevents this range from being strictly comparable with that of sun-spots. It will be seen that after the date of peculiarity *a* (Figs. I. and II.) the sun-spot curve marches rapidly up, while the declination-range curve does not so mount; also, after the maximum *b*, the sun-spot curve falls more rapidly than the declination-curve. Similar remarks will apply to other points; in fine we have grounds for supposing the declination-range to be acted upon by some other influence than one so represented by sun-spots as to follow their increase and diminution.

Mr. J. A. Broun, in a series of interesting investigations, has indicated the probability that there is an influence of this nature; and it may fairly be said that the results of this paper are at least consistent with such an hypothesis.

20. I would next remark that the hypothesis asserting a connexion of some kind between magnetical and meteorological phenomena appears to be borne out by the results of this paper *.

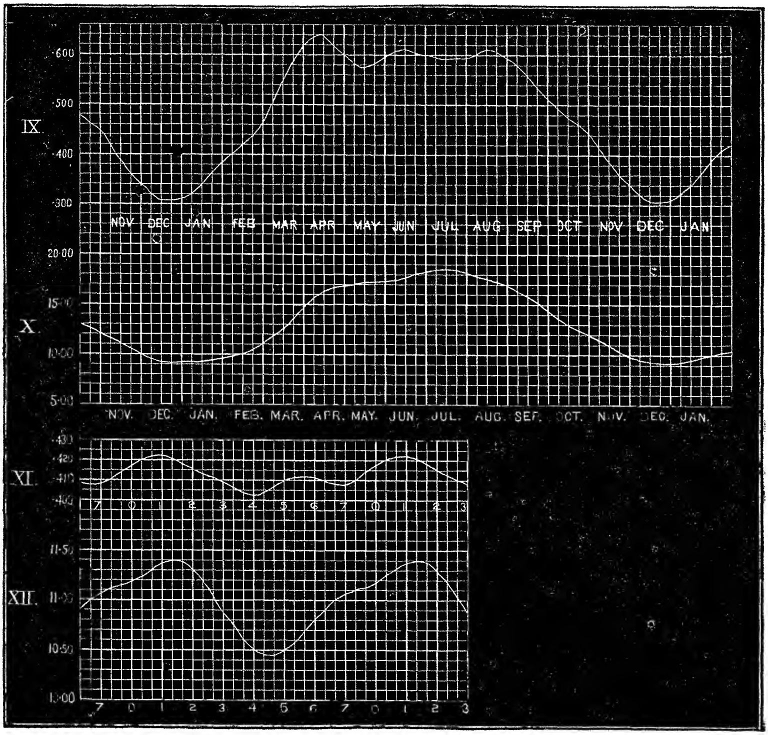
It will be noticed from Figs. XI., XII. (p. 120), that there is a striking likeness between the winter lunar variation for the declination and temperature ranges. There is also a likeness between the summer lunar variation for these two elements, not so striking to the eye, but which will nevertheless be seen from the following comparison:—

| Phase of lunation... | (0) | (1) | (2) | (3) | (4) | (5) | (6) | (7) |
|---|---|---|---|---|---|---|---|---|
| Summer lunar variation temperature-range | 16·96 | 17·02 | 17·23 | 17·22 | 17·35 | 17·15 | 17·24 | 17·27 |
| Summer lunar variation declination-range | ·620 | ·600 | ·578 | ·586 | ·609 | ·604 | ·584 | ·596 |

Both of these, the first imperfectly and the latter fully, exhibit maxima at or near new and full moon. Again, while on the whole there is a likeness between the curves representing the annual variation for these two elements, yet there is also a dissimilarity, inasmuch as the declination-curve (Fig. IX.) has apparently a strong reference to the equinoxes, which is absent, or nearly so, in the temperature-curve. But it may be taken for granted that if there be a connexion between magnetism and meteorology, it certainly cannot be of such a nature that all the meteorological peculiarities of a place are reproduced in its magnetic phenomena, for all observation is against a connexion of this description. Indeed any hypothesis of a connexion between these two must, in order to be consistent with facts, assume that the magnet averages things so as to be free, in a great measure if not completely, from local peculiarities.

* Mr. Baxendell, of Manchester, was the first to direct attention to this subject in a paper "On a Diurnal Inequality in the Direction and Velocity of the Wind," apparently connected with the daily changes of magnetic declination. See Memoirs of the Lit. and Phil. Society of Manchester, vol. iv. ser. 3, p. 210.

The results of this paper appear to be consistent with such an hypothesis when so modified.




21. It is needless here to enter into the various reasons which induce us to believe in the existence of a connexion between the meteorology of the earth and the physical state of the sun's surface. I may, however, refer to a paper "On the Daily Range of Atmospheric Temperature at the Kew Observatory" (Proc. Roy. Soc. 1877, vol. xxv. p. 580), in which it was shown that at Kew the temperature-range is somewhat higher at times of maximum than at times of minimum sun-spots. If, however, we plot as a curve this temperature-range, it is neither like Fig. I. nor Fig. II., or at least not so like as to suggest any marked relation to the eye. (This curve is not given in this paper.) But on examining its most prominent points, I find that not a few of these agree both in direction and in time with similar peculiarities in the magnetic curve. Thus there is a well-marked prominence in the temperature-range curve corresponding to about the end of May 1861; now there is a prominence in the magnetic curve at about the same date. Again, there is a depression in both curves corresponding to about the end of May 1862. Again, there is a well-marked depression in the temperature-curve corresponding to the end of April 1866, while in the

declination-curve there is a well-marked depression perhaps a month later. Finally, there is a depression in the temperature-curve corresponding to the beginning of July 1867, and one in the declination-curve corresponding to the middle of August. I have not been able to notice any marked coincidence between the temperature-range and the sun-spot curves.

Without attempting to decide the question, it appears that there is at least some preliminary evidence in favour of an alliance between the three phenomena, solar spotted area, terrestrial meteorology, and terrestrial magnetism, of such a nature that the variations of the former precede those of the other two in point of time. It will be seen that this is a question of much importance; for if there be a connexion of this nature, once its laws are known, it may become possible to foresee the character of impending meteorological changes. These points, however, can only be determined by further investigations.

I desire, before concluding, to thank Mr. Wm. Dodgson, who has given me much assistance in the calculations and diagrams of this paper.

The Society then adjourned over the Easter Recess, to Thursday, April 12.

*Presents received, March* 1, 1877.

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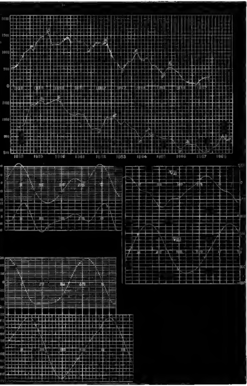
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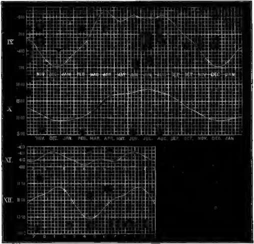

IX
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